Effect of b-value on DTI sensitivity in revealing myocardial structure degradation in rabbit models with acute myocardium infarction

Yin Wu[1,2], Chao Zou[1,2], Wei Liu[1,2], Wei-Qi Liao[1,2], and Ed X. Wu[3,4]

[1]*Paul C. Lauterbur Research Center for Biomedical Imaging, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong, China, People's Republic of,* [2]*Key Lab of Health Informatics, Chinese Academy of Sciences, Shenzhen, Guangdong, China, People's Republic of,* [3]*Laboratory of Biomedical Imaging and Signal Processing, The University of Hong Kong, Pukfulam, Hong Kong,* [4]*Department of Electrical and Electronic Engineering, The University of Hong Kong, Pukfulam, Hong Kong*

Introduction Diffusion tensor imaging (DTI) has been recognized as a powerful tool to nondestructively investigate ordered microstructure of biological tissues. The basic assumption of the conventional DTI is that water diffusion complies with Gaussian process, which results in monoexponential decay of diffusion weighted signal with b-value. However, the signal decay was found to significantly deviate from the monoexponential model with increase of diffusion weighting strengths in some complex tissues, such as neural, kidney and heart [1-5]. Recently, diffusion sensitivity dependence of DTI indices has been confirmed in developing neural tissues [6]. In the current study, effect of b-value on longitudinally detecting myocardial structural alteration was assessed in rabbit models with acute myocardium infarction (AMI), providing information of optimizing diffusion imaging protocol and analysis in characterizing myocardial microstructural changes in pathological states.

Method Imaging experiments were conducted on a 3T Siemens Trio MR scanner. LCX ligation was performed on 24 New Zealand adult rabbits with infarctions typically induced at lateral wall. Infarcted animals together with 6 controls were sacrificed at day 1, 3, 5, and 7 after infarct surgery (N = 6 for each group) with denoted as D1, D3, D5 and D7, respectively. The excised hearts were fixed with formalin and imaged with segmented EPI-DTI [7] along the short-axis of LV with parameters: TR/TE = 4000/95 ms; slice thickness = 1.2 mm, slice gap = 0.2 mm; gradient direction = 6; number of slices = ~13; in-plane resolution of 0.78 mm^2; non-zeros b values of 500 to 3000 s/mm^2 with a step of 250 s/mm^2; and NEX = 4. The scan time was ~2.5 hr per sample. Fractional anisotropy (FA), mean diffusivity (MD), axial and radial diffusivities were computed pixel by pixel from DWIs with two b values (i.e., 0 vs. 11 non-zero b-values, respectively). Each slice was segmented into septum, anterior, lateral and posterior as described in [8]. In infarct group, the segment with the center of infarction located was identified as infarct region, of which the bilateral segments were adjacent region, and the remaining part was remote region. For control group, lateral wall was arbitrarily regarded as sham infarct region with sham adjacent and sham remote regions subsequently defined (Fig. 1). For each sample, 6 representative slices covering infarction were selected, from which DTI indices at specific b-value were measured and averaged among slices and six samples of a group in three regions. ANOVA and pos-hoc SNK multi-comparisons were performed to assess the impact of b-value on revealing dynamic myocardial structural degradation post-AMI with $p<0.05$ regarded as statistically significant. At each b-value, the overall sensitivity was assessed as the total number of statistical significances found among all the groups.

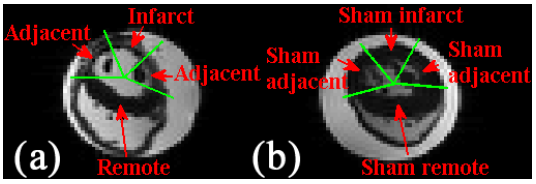

Fig. 1 Region definition.

Results Logarithmic decay of normalized diffusion-weighted signal intensities averaged along 6 diffusion direction with b-value was found to clearly deviate from the basic monoexponential model in all groups (Fig. 2), confirming the non-monoexponential diffusion behavior with increase of diffusion strength in both normal and infarct groups. FA of all infarct groups decreased substantially at all b-values in both infarct and adjacent regions compared to controls, reflecting the loss of fiber orientation integrity with the onset of MI. The sensitivities of detecting FA change were found to be the greatest at b-values from 750 to 2750 s/mm^2, with the total number of statistical significances of 3 in infarct region (control vs. D1/D5/D7, respectively) and 2 in adjacent region (control vs. D5/D7, respectively). The numbers of statistical differences decreased to 2 at b-value of 3000 s/mm^2 in infarct region (control vs. D5/D7, respectively), and further reduced to 1 at b-value of 500 s/mm^2 in both regions and b-value of 3000 s/mm^2 in adjacent region where significant difference only shown between control and D5 (Fig. 3a-b). No apparent

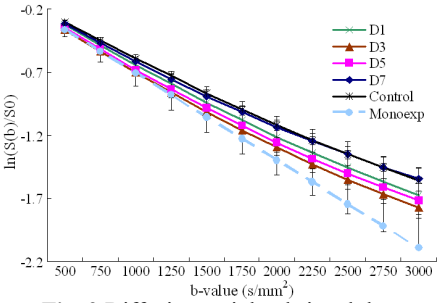

Fig. 2 Diffusion weighted signal decay.

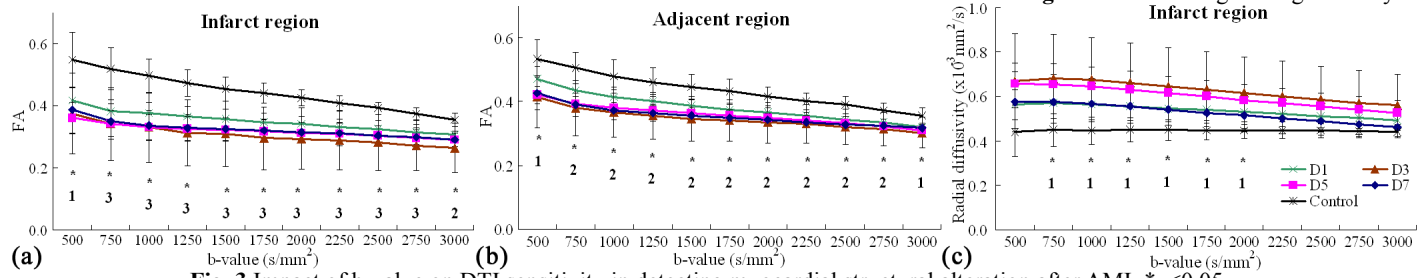

Fig. 3 Impact of b-value on DTI sensitivity in detecting myocardial structural alteration after AMI. *$p<0.05$.

alteration of MD and axial diffusivity was found at all regions (not shown). Meanwhile, conspicuous increase of radial diffusivity of the all infarct groups due to myocyte hypertrophy was observed only in infarct region, with the highest sensitivity occurred at b-values from 750 to 2000 s/mm^2, within which significant difference exhibited between control and D5 (Fig. 3c).

Discussion In this study, influence of b-value on detecting myocardial structural degradation was explored in rabbit models with AMI. Non-monoexponential diffusion manner was confirmed in both infarct and control groups, which was in good agreement with previous studies [3, 4]. Averaged SNR of diffusion weighted images was ~90 and ~25 at the lowest and highest b-values, respectively, ensuring adequate SNR for DTI quantification [9]. FA and radial diffusivity were found to alter significantly in infarct and/or adjacent regions, and the sensitivity to detect their statistical differences among control and 4 infarct groups were b-value dependent. Typically, b-value within the range of 750 to 2000 s/mm^2 yielded good sensitivity in detecting myocardial structural degradation. The experimental results demonstrated the important effect of diffusion strength on DTI index characterization and emphasized the necessity of optimizing b-value for better monitoring and detecting myocardial structural alteration.

References [1] Niendorf T et al, 1996; [2] Clark CA et al, 2000; [3] Forder JR et al, 2001; [4] Hsu EW et al, 2001; [5] Wittsack HJ et al, 2010; [6] Hui ES et al, 2010; [7] Porter DA et al, 2009; [8] Chen J et al, 2003; [9] Bastin ME et al, 1998.

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